Multi-pion analysis in the MPD

Seb Jones

Department of Physics & Astronomy
University College London

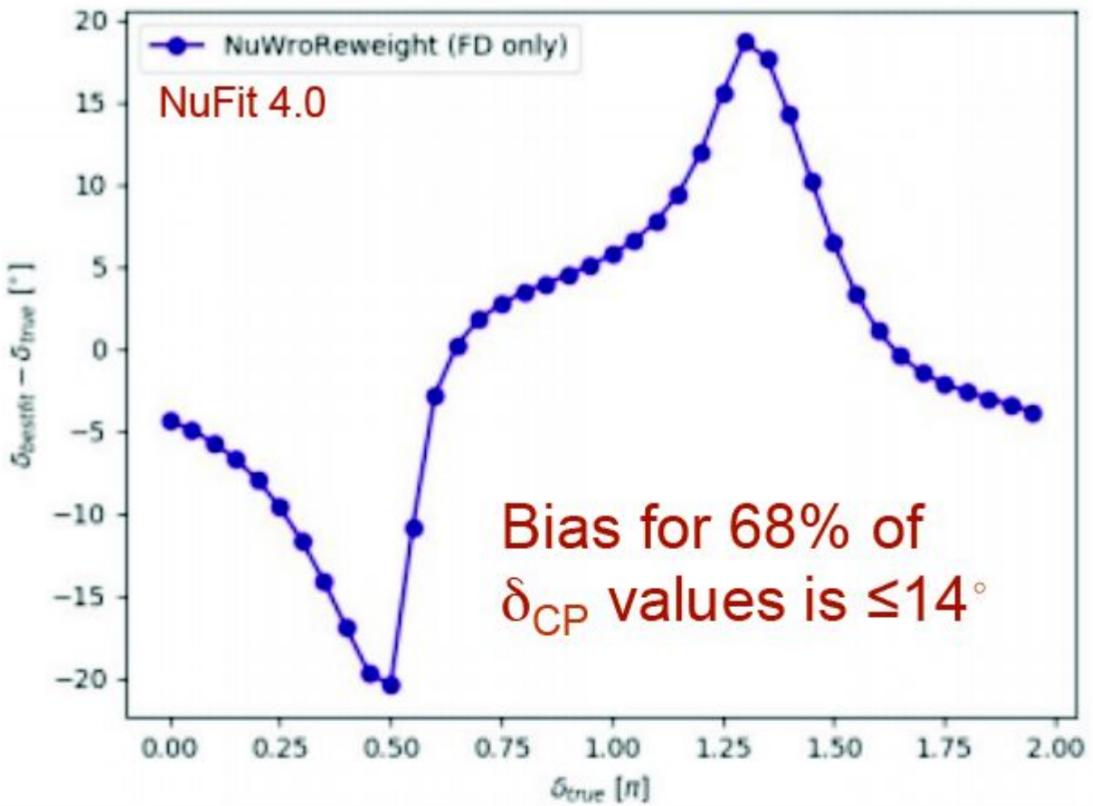
March 18, 2020

Motivation

- As I showed at the last CM, the PID capabilities of the HPgTPC allow different exclusive final states to be separated out – further details here
- In turn, differences in the interaction model can be determined through differences in kinematics for these final states
- We want to propagate these differences through to our FD samples which allows us to (hopefully) fix the issue

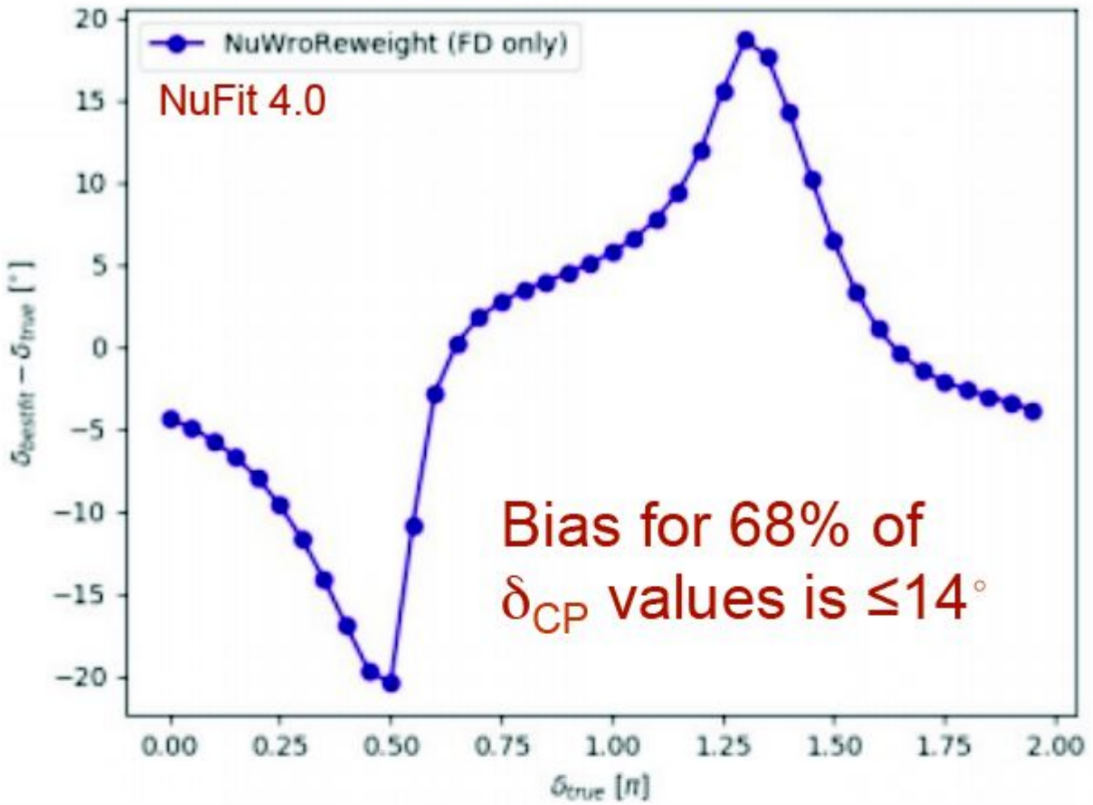
Background: NuWro mock data

- FD-only fit using NuWro as data but fitting with GENIE as the reference model gives a good fit with a low χ^2
- However, a bias is induced in the value of δ_{CP}



Background: NuWro mock data

- With the inclusion of a near detector in the fit, the χ^2 blows up – we would see there is an issue with our model
- However, it doesn't necessarily show us how to fix the problem



Simulations

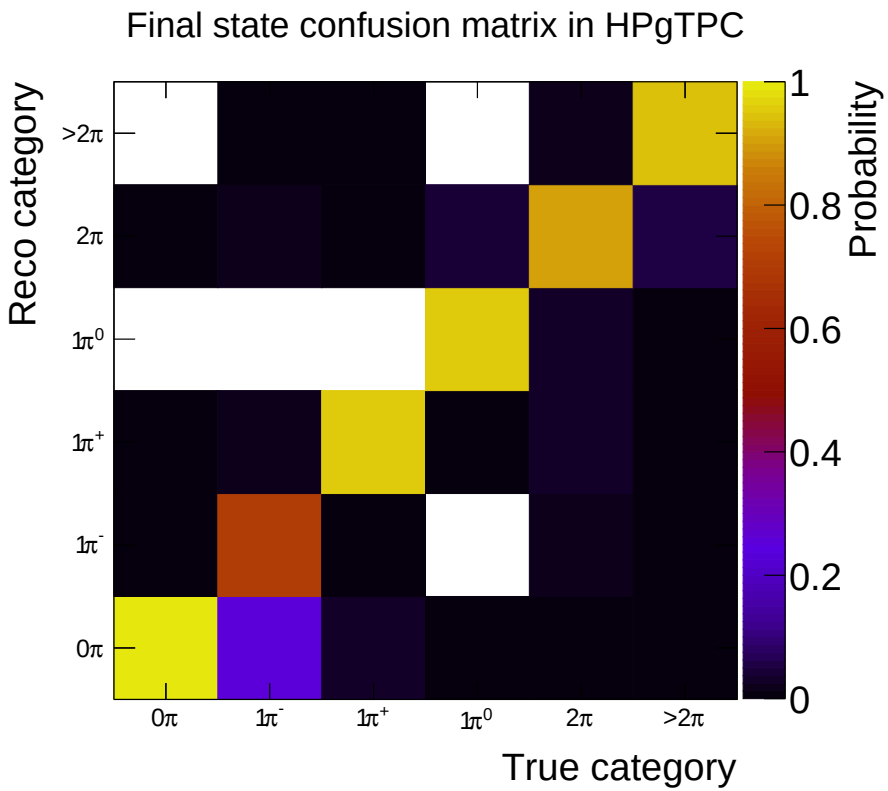
- MPD simulated using GENIE and edep-sim
- Parametrised reconstruction using Gluckstern formula is used to estimate energy of tracks
- Track length of 6cm is required for charged particles to be reconstructed
- For charged pions and protons with $p < 1.5\ GeV/c$ assume perfect separation by dE/dx
- For $p > 1.5\ GeV/c$, use E/p from the the ECAL
- For π^0s, require that decay photons are over threshold and not collinear for reconstruction

Strategy

- Compare our nominal (GENIE) MC with the NuWro-reweighted version in the HPgTPC in some reconstucted kinematic space for reconstructed exclusive final states
- Take our nominal (GENIE) FD Monte Carlo and reweight events based upon their true kinematics and final state using this information derived from the ND
- Compare our FD 'data' (NuWro mock data) to this reweighted MC in a FD-only fit

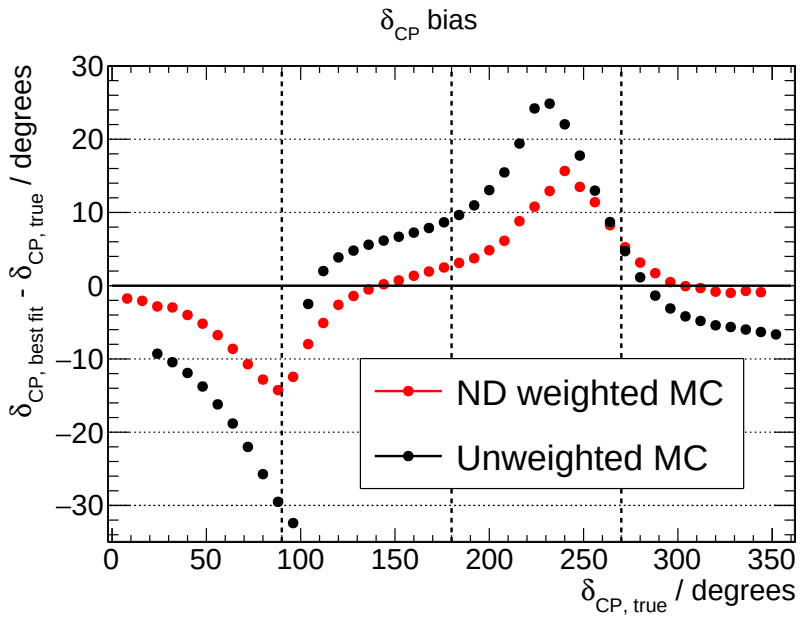
Final states in the HPgTPC

- As mentioned previously, the HPgTPC has excellent PID capabilities
- The confusion matrix shows that, for all of the chosen final states, the true category is reconstructed $> 70\%$ of the time



Choice of kinematic variables

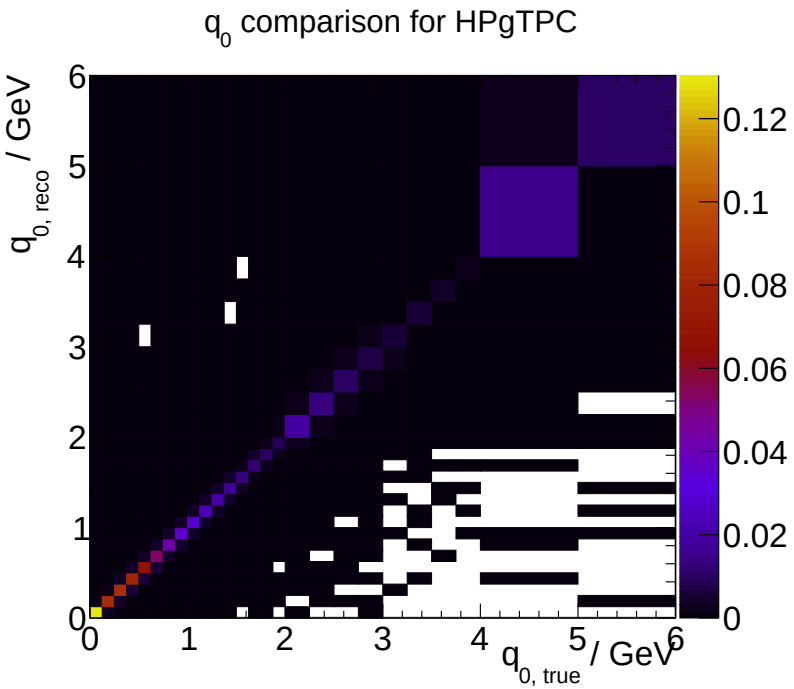
- Previously I had looked at reweighting in Q^2_{exp} where, $Q^2_{exp} = 2E_\nu(E_\mu - p_\mu cos\theta_\mu) - m^2_\mu$
- This yielded some good initial results in reducing the bias in δ_{CP} in FD-only fits (see right) but improvements were definitely possible

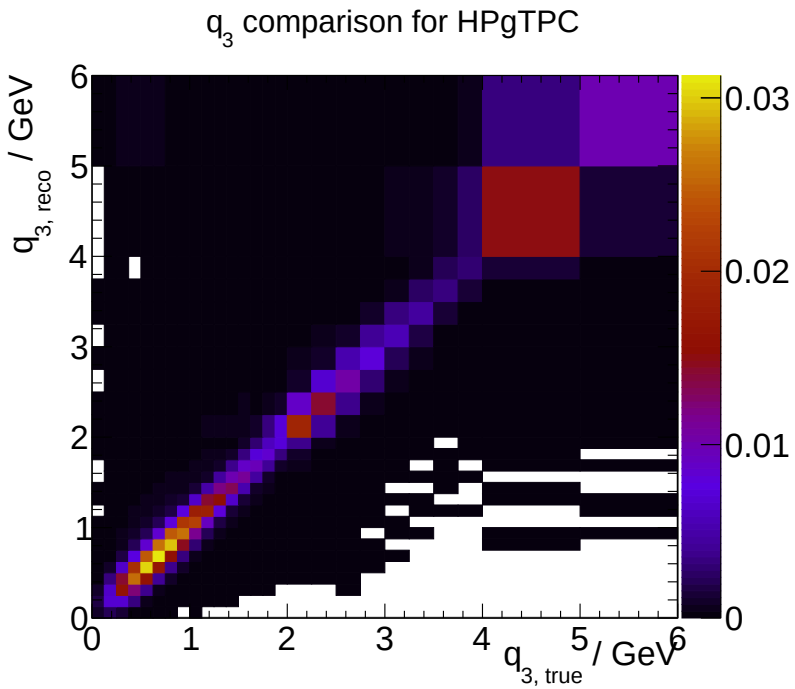


Reweighting in q_0, q_3

- Better results are probably possible reweighting in a 2-dimensional kinematic space
- In this case, chose the energy transfer, q_0 and the 3-momentum transfer, q_3
- Define true q_0 as E_{avail} where, $E_{avail} = T_p + E_\pi$
- Similarly, define $q_3 = \sqrt{Q^2 + q_0^2}$ where, $Q^2 = 2(E_\mu + E_{avail})(E_\mu - p_\mu cos\theta_\mu) - m_\mu^2$ and q_0 is as above

q_0, q_3 migration matrices

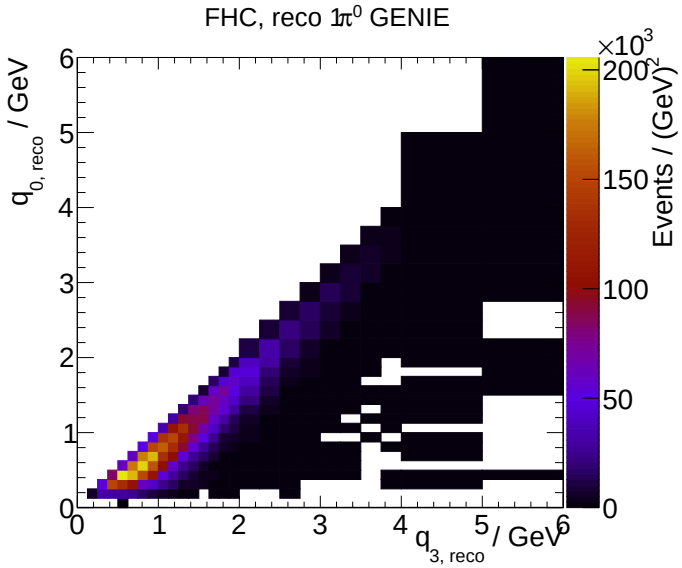


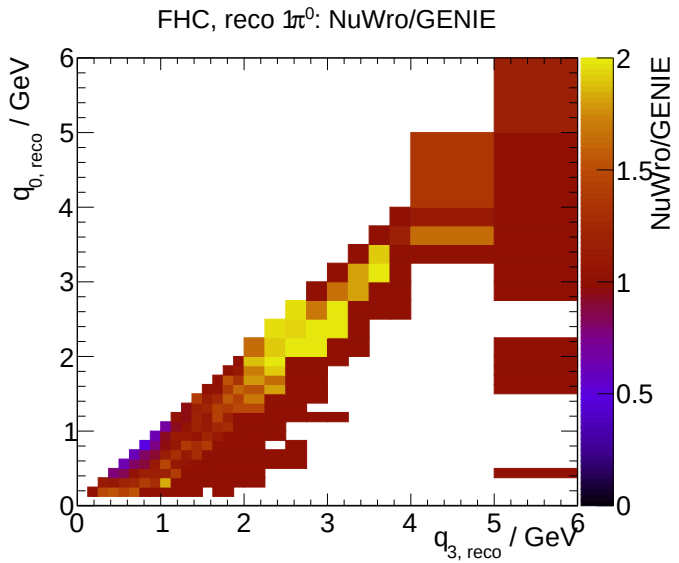


- Without the use of E_{avail}, matrices become significantly less diagonal due to energy lost as neutrons
- The full complement of these matrices for exclusive final states are shown in the backup

Exclusive final states used

- For each exclusive final state produce a ratio of NuWro to GENIE in q_0 and q_3
- Divide 0π into single proton and more than > 1 proton
- This helps to pick out the differences in quasielastic and 2p2h events
- Other chosen final states are $1\pi^{\pm}$, $1\pi^0$, 2π and $> 2\pi$
- Separate histograms for FHC and RHC

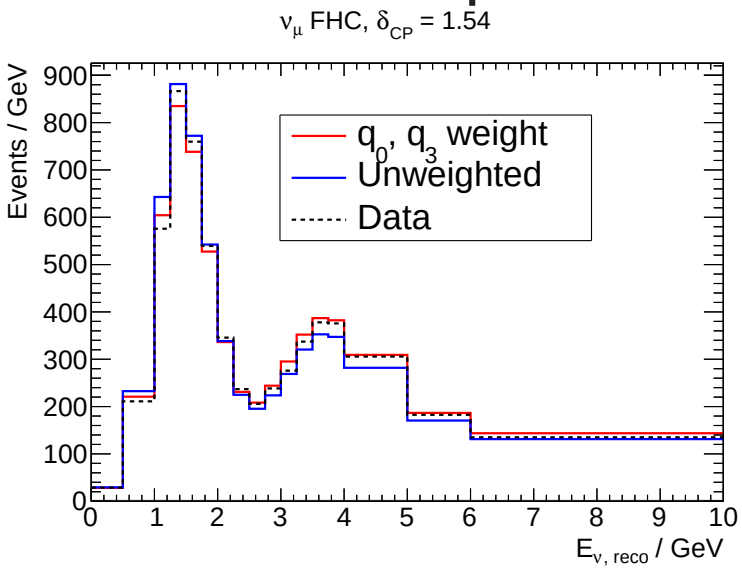


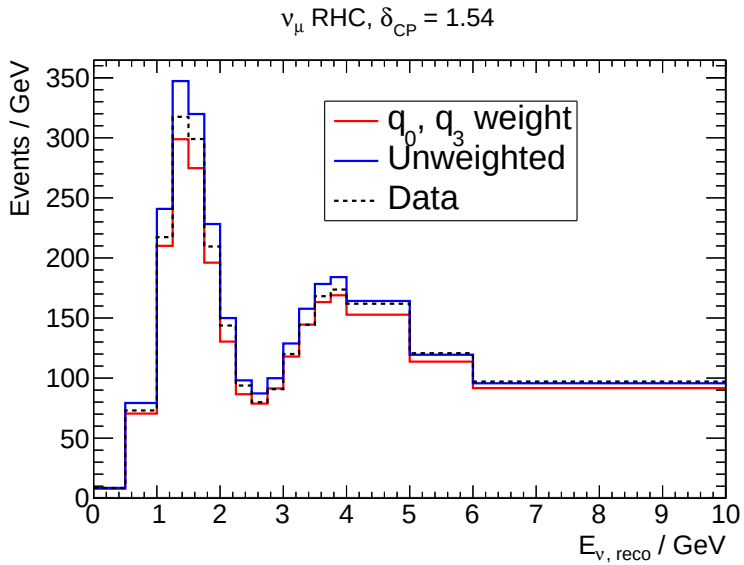


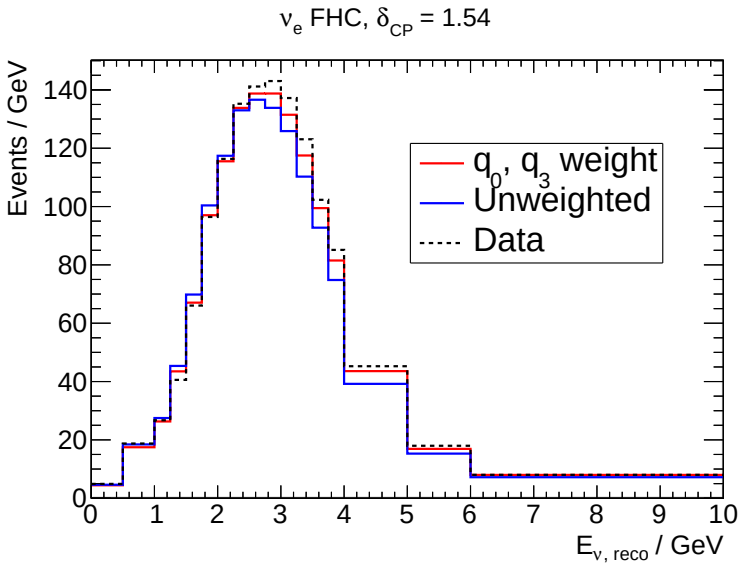
CC inc. reweighting

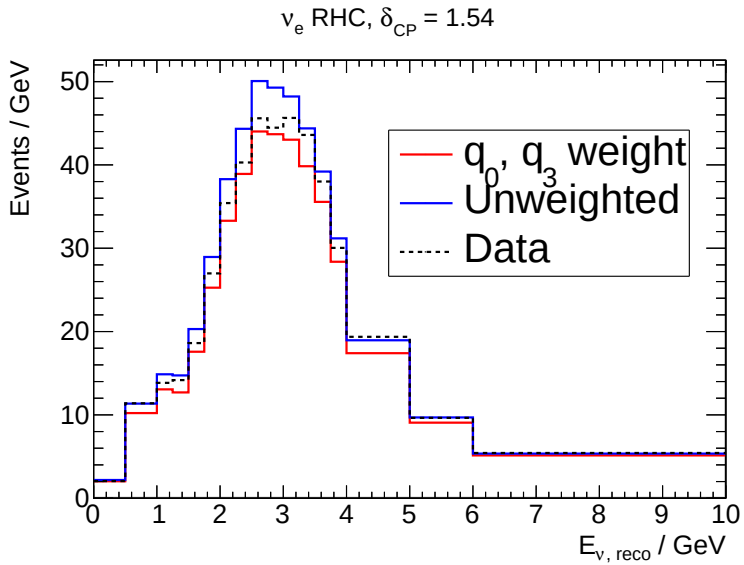
- Additionally, wanted to compare this reweighting with the a sample where we are unable to separate out final states easily
- In this case, use a single q_0, q_3 histogram regardless of final state
- Describe this as 'CC inc. weighting'

Far detector samples

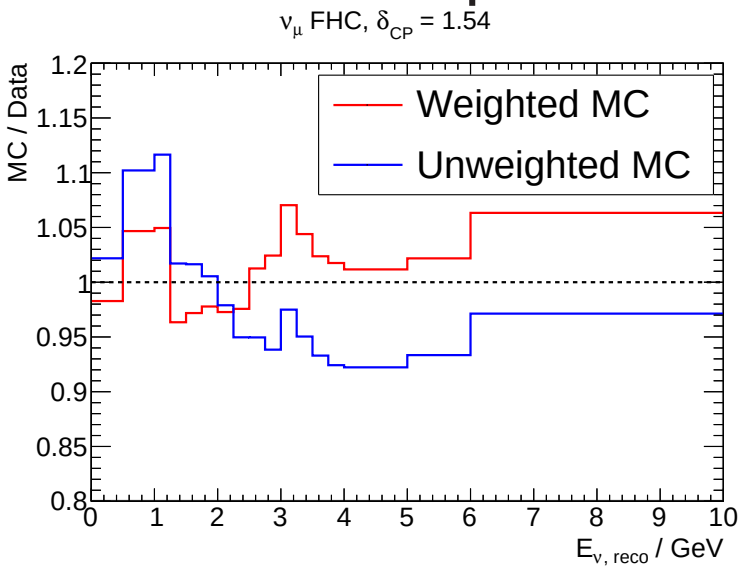


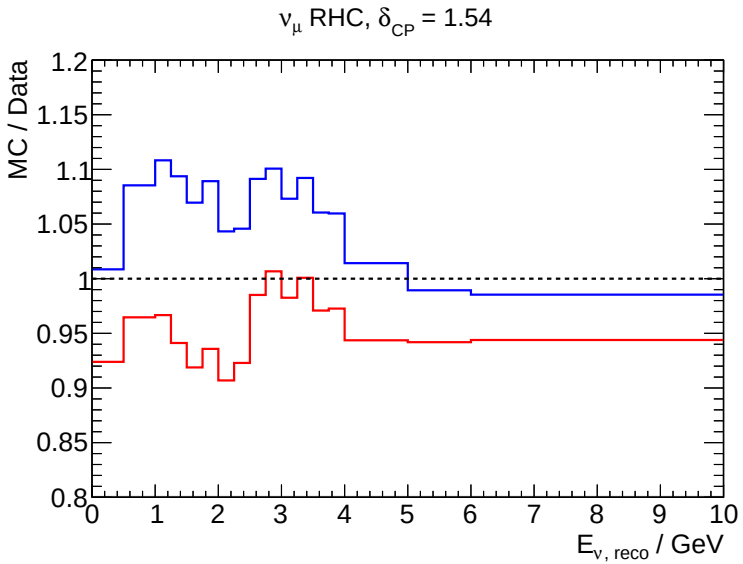


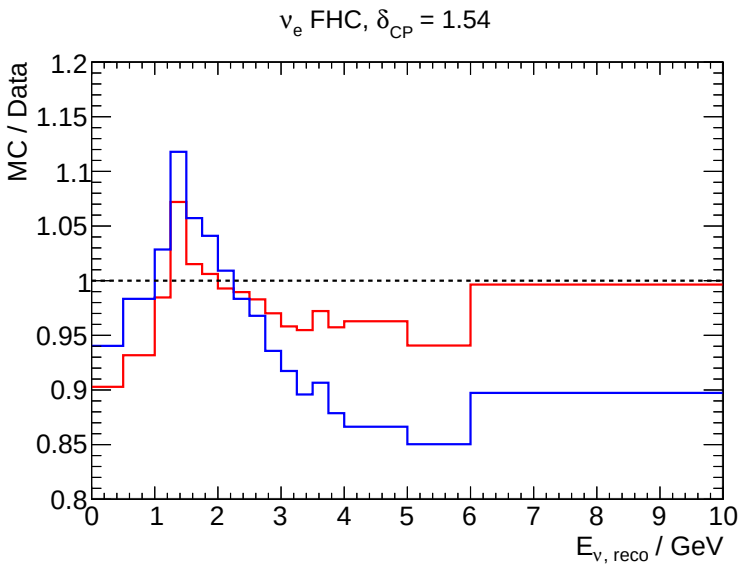


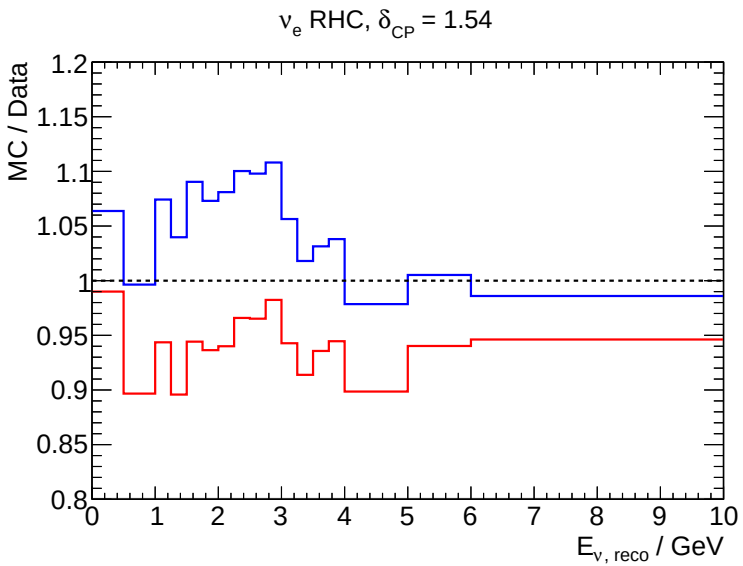


Far detector samples

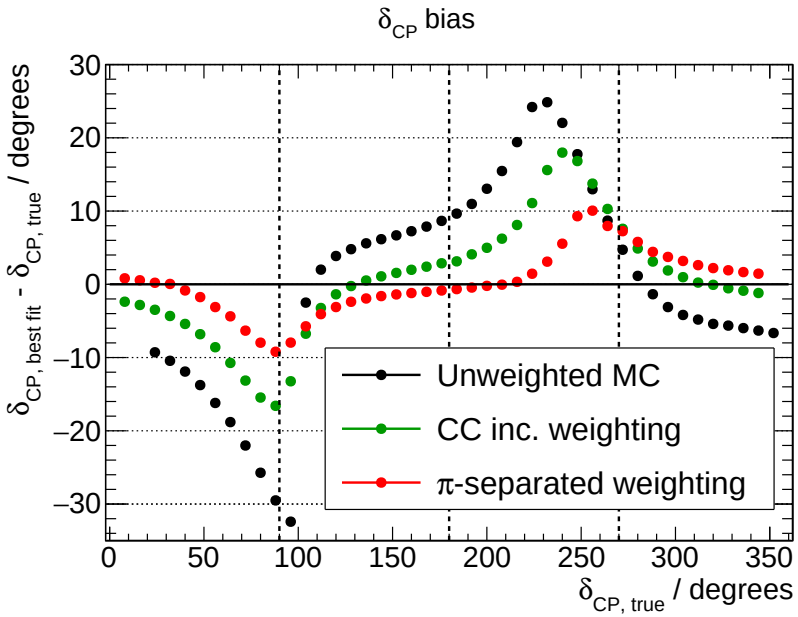


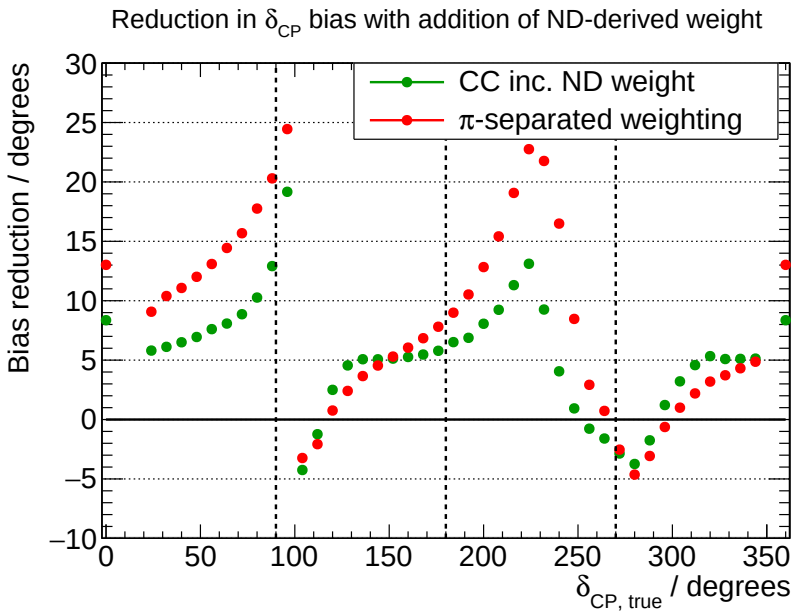






Fitting results





- One metric of how well this reweighting is doing is to identify the value which 68% of biases are below
- For the unweighted MC this is 16.2°, for the π-separated weighting it is 4.4° and for the CC inc. weighting it is 8.6°

Next steps

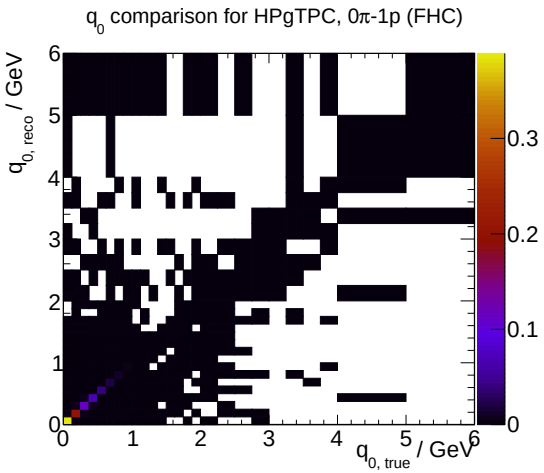
- The ideal would be to get this rewighting to the point where it works with and ND+FD fit – currently still working on this
- Additionally, working on using q_0, q_3 distributions derived from simulated exclusive LAr samples to show the difference from the HPgTPC

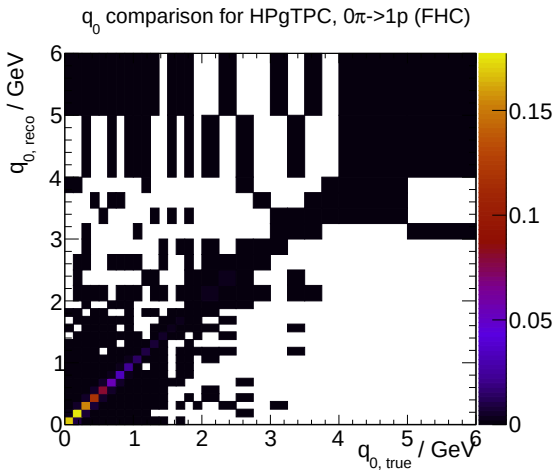
Conclusions

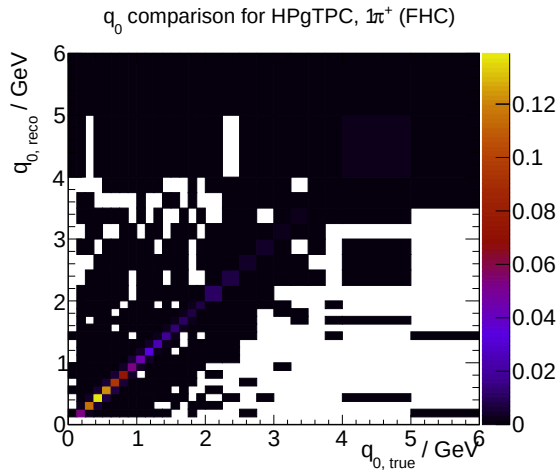
- The MPD has the ability to separate a variety of exclusive final states
- By reweighting in some kinematic space and these final states it should be possible to correct for deficiencies in our interaction model
- When using NuWro mock data with a GENIE reference model, reweighting in q_0 and q_3 it is possible to greatly reduce the observed bias in δ_{CP}
- The bias for 68% of values is reduced from 16.2° to 4.4° in this case

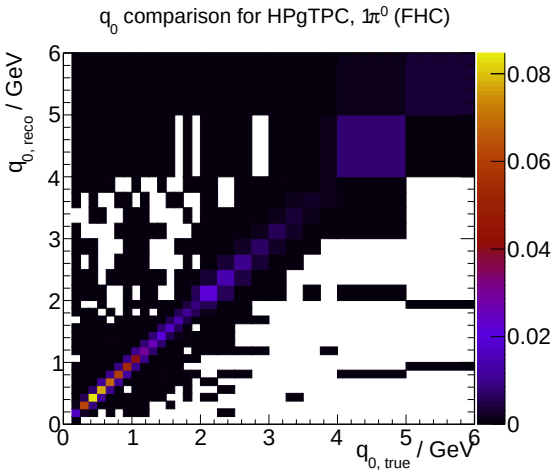
Backup

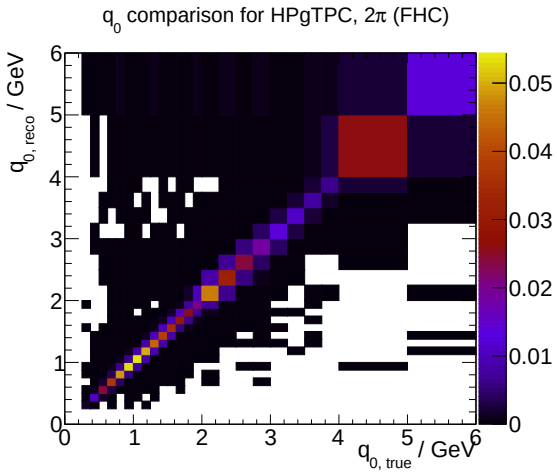
q_0 migration matrices

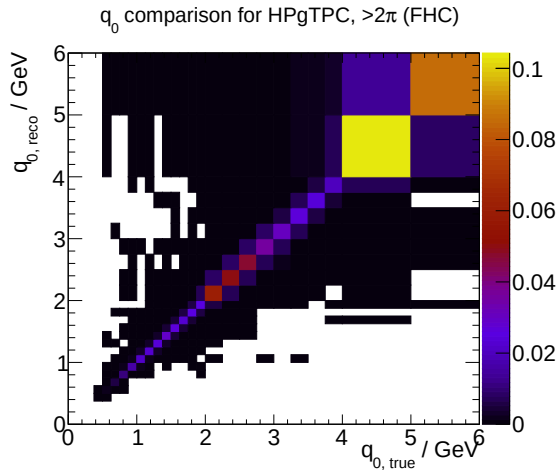






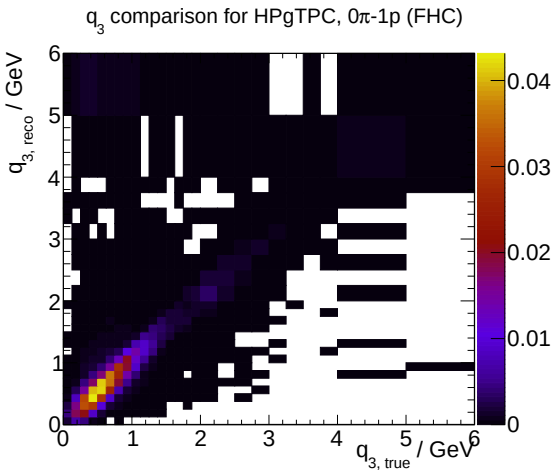


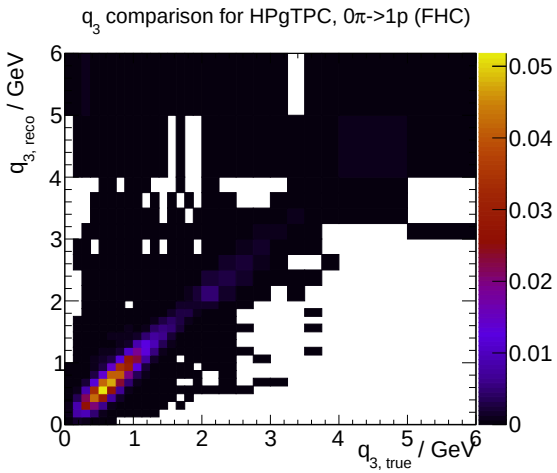


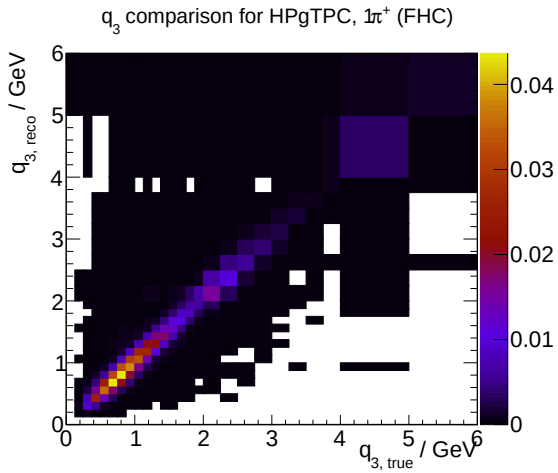


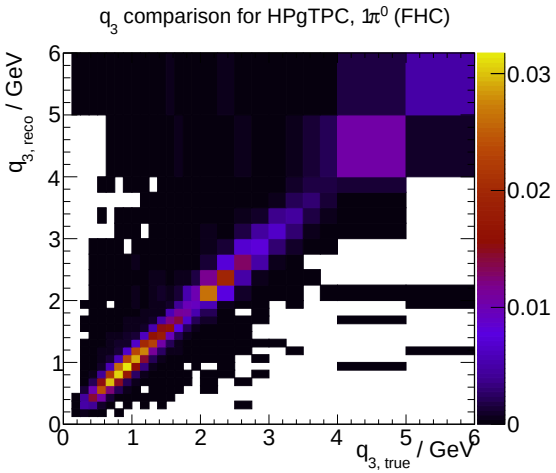
Units are fraction of events in sample

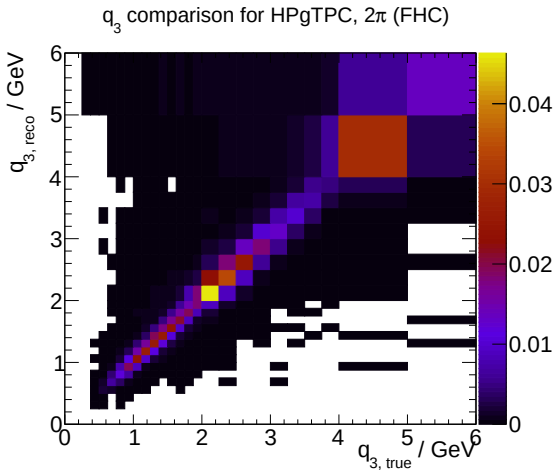
q_3 migration matrices

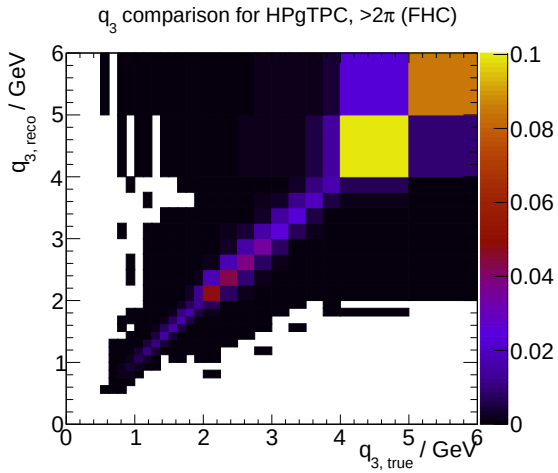






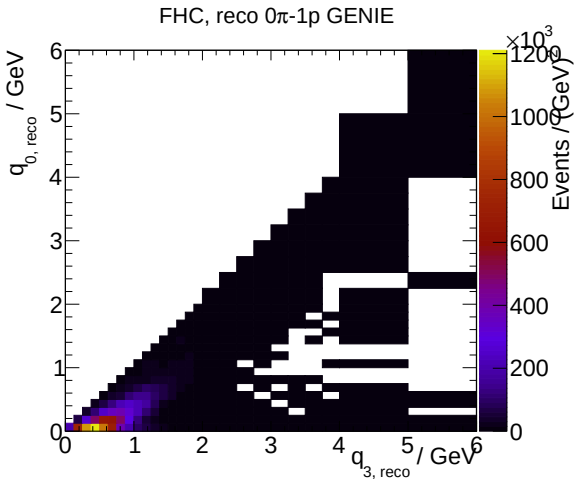


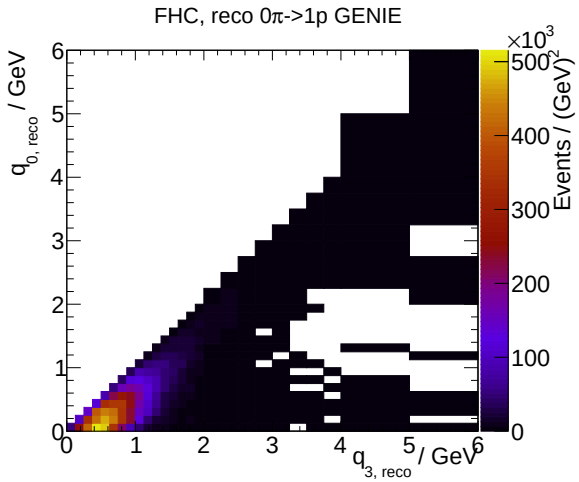


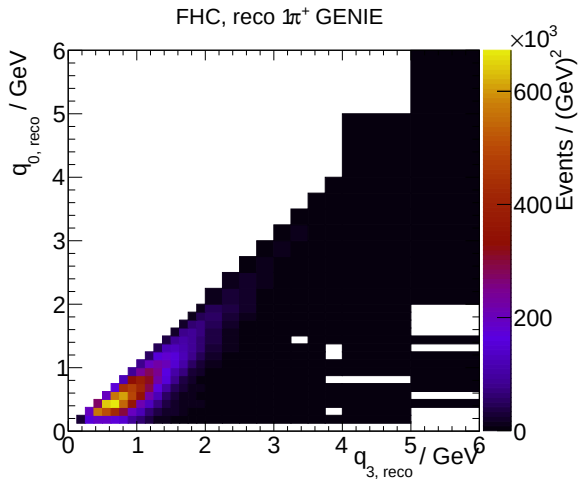


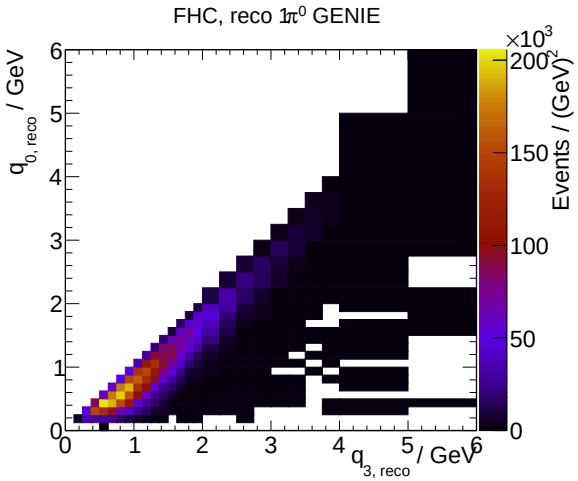
Units are fraction of events in sample

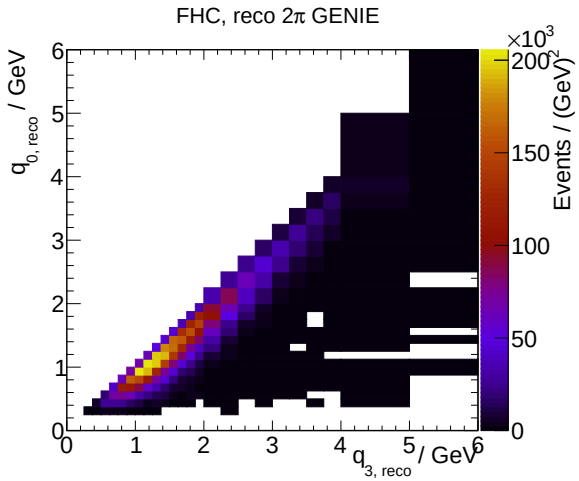
q_0, q_3 for exclusive final states in HPgTPC

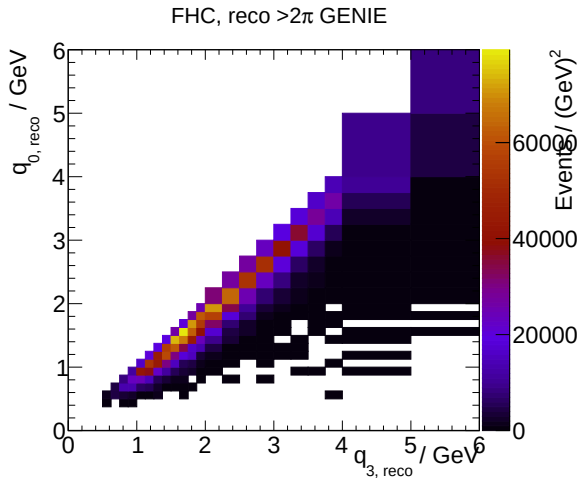












NuWro/GENIE ratios for exclusive final states in HPgTPC